Pest Management Grants Final Report

Project Title: Monitoring Noctuid Pests in Row Crops Using Pheromone Traps

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Contractor name: Regents of University of California

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Prepared for the California Department of Pesticide Regulation

Disclaimer

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Executive Summary

Growers of tomatoes and melons control noctuid worm pests with applications of pesticides that are toxic to humans and/or disruptive to beneficial insects and bees. Practices that better target pesticide applications to periods when crops risk economic damage reduce the amount and frequency of conventional pesticide applications and improve the efficacy of reduced-risk pesticides. Monitoring tools, such as pheromone traps and degree-day phenology models, have been successfully used in tree crops to time sprays for several pests. The overall goal of this project was to demonstrate to professional crop advisors (PCAs) and vegetable/row crop growers how to use degree-day models to monitor worm pests in row crops in order to increase the efficacy of reduced-risked pesticides by improving the timing of applications.

The project was conducted across 8 counties in the Central Valley, representing 211,687 acres of tomatoes and melons. A total of 19 field trap sites were established across that area. There was a team effort managing this project. Eight UCCE Farm Advisors conducted training of PCAs and growers. Six UCCE Field Assistants established and maintain trap sites. Seventeen PCAs conducted weekly evaluation of crops for eggs and worm presence, and 2 information system experts set up a web site to disseminate trap counts and biofix occurrence across the State (IPM web site).

One organizational meeting was held in March 2001 with the participation of Farm Advisors, IPM specialists and Field Assistants involved in the project. Five meetings were conducted between May and June 2001 to train PCAs to use pheromone traps and degree-days models. One educational bulletin on operating pheromone traps was published in May 2001. A demonstration of the project for tomato growers was held to show the potential of monitoring pests for better timing of pesticide application and final conclusions were presented in two multi county meetings.

Trap counts of six noctuid species (Beet armyworm, Black cutworm, Tomato fruitworm, Cabbage looper, Variegated cutworm, and Western yellowstriped armyworm) were recorded from 19 sites across 8 Counties every week. A web site was set up to post and disseminate records of weekly trap counts and accumulated degree-days for every species and field site. The records on the web site were updated every week, presented in graph format and accessible to the PCAs to follow trap counts and degree-days accumulation in real time. PCAs also sampled crops for worms and eggs. These samples were raised to adult stage for identification and determination of parasitized worms.

Data obtained from pheromone traps and field scouting showed that Cabbage looper was the preponderant species found in the 2001 season and showed that phenology models accurately predicted new hatches in the field. It has been also demonstrated to PCAs the usefulness of pheromone traps as monitoring tool. Through this project it has been possible to develop a statewide system for monitoring noctuid pests. The IPM website provides growers and PCAs with the information they need to track which pests are the most important and to know when they should expect an economically significant worm population in their regions. PCAs can now use trap information to improve field monitoring and time pesticide applications.

Introduction

The primary goal of this project was to demonstrate to professional crop advisors (PCAs) and growers how to monitor worm pests in row crops in order to reduce the amount and frequency of conventional pesticide applications and increase the efficacy of reduced-risked pesticides by improving the timing of applications. Growers of tomatoes (freshmarket and processing) and melons control noctuid worm pests, such as beet armyworm, tomato fruitworm, and cabbage looper, with applications of pesticides that are toxic to humans (methamidosphos, carbaryl, and methomyl) and/or disruptive to beneficial insects and bees (pyrethrin). The efficacy of reduced-risk pesticides, such as bacillus thuringiensis (Bt) and spinosad (Success™) can be improved through practices that better target pesticide applications to periods when crops risk economic damage.

The objective of the project was to extend research results from past projects by demonstrating how to use degree-day models and pheromone traps to monitor worm pests in row crops. Using pheromone traps and degree-day models to time sprays to the period of the most potential for economic damage can reduce the cost of pest control and reduce the impacts of pesticide on environment. Previous research conducted by the participants of this project has shown that pheromone traps and degree-day models for beet armyworm, tomato fruit worm, and variegated cut worm accurately predict generation cycles at a regional scale. However, using degree-days in the field had not been tied to practical application in the field. In the past determining the beginning of an insect generation cycle in the field limited the usefulness of degree-day models, but developments in adult pheromone traps has provided a easier method to determine the start of a generation cycle, known as a biofix.

The project was conducted across 8 counties in the Central Valley, representing 211,687 acres of tomatoes and melons. It involved the joined effort of 8 UCCE Farm Advisors and 6 UCCE Field Assistants, covered 19 field trap sites across the study region and included the active participation of more than 15 PCAs that work in the region.

The specific objectives of this project included

1. Organization of procedure protocol with project participants. This task included meetings with participants aimed to discuss different course of actions and assign responsibilities to participant PCAs, Farm Advisors and Field Assistants.

2. Train PCAs in each region to use pheromone traps and degree-day models for monitoring worm pests. This task included: a) developing an educational bulletin on using the pheromone traps and degree-day models, b) conducting training meetings to teach PCAs how to use traps, degree-day models, and identify worm species.

3. Demonstrate how to use degree-day models and disseminate trap data. This task included: a) monitoring adult moths with pheromone traps at 2-4 study-sites per county, b) determining the biofix of a new generation, c) calculating cumulative degree-days for each worm species and d) setting up a web page for data dissemination.

4. **Monitor larvae populations in field sites and demonstrate the use of phenolgy models to predict worm activity, data analysis and presentations.** This task involved a) weekly evaluating and sampling of crops for eggs and worms, b) raising worm larvae and eggs to adult stage to identify species c) data analysis and meeting presentations.

Result and discussion

Objective 1: Organization and discussion of the procedure protocol among participants.

In March 2001 an organizational meeting was held in Sacramento Co. UCCE office aimed to discuss different course of actions and assign responsibilities to participants. Project principal investigator (PI) would provide overall coordination for project. Co-PIs would coordinate calculations of degree-days from CIMIS weather data and coordinate identification of larvae. Farm Advisors would conduct training of PCAs and growers in their counties. Field Assistants would establish and maintain study sites in each county.

IPM specialists were present and their input was very valuable in discussing the best way to proceed to achieve the main goals of the project. A DPR Agent participated in the meeting, and informed the group about the administrative framework for budget management. Also, Farm Advisors showed previous year results of moth trapping, and discussed publication of material for species identification. A great degree of commitment and clear share of responsibilities among participants was the overall accomplishment of the meeting.

Objective 2: Training meetings for PCAs from each County to use pheromone traps and degree-day models.

The following tasks were involved in the accomplishment of this objective:

Task 2.1. Bulletin Publication: An educational bulletin was published in May 2001 (Appendix A). It contained a thorough description of pheromone trap, guidelines to select a suitable trap site, and instructions on how to set up, operate and service traps.

Task 2.2. Training meetings: Five training meetings were held in Yolo, Colusa, San Joaquin, Stanislaus and Merced Counties between May and June 2001. More than 15 PCAs were trained on using pheromone traps and degree-day models. These PCAs agreed to collaborate in the project by collecting data and scoring worm infestation in the fields they visit and by sending worm samples from the fields for identification purposes. The PCAs were given a protocol to follow (Appendix B) to score larvae presence in the field, a key for adult noctuid pest identification and all the material they needed to sample and identify worms and eggs: coolers, notebooks, worm/egg identification key, plastic bags, etc.

Objective 3: Trap monitoring demonstration and dissemination of the data collected.

The following tasks were involved in the accomplishment of this objective:

Task 3.1: Trap Monitoring: Pheromone traps were placed in nineteen sites to monitor, on a weekly basis, six different species of noctuid moths: Beet armyworm (BAW), Black cutworm (BCW), Tomato fruitworm (CEW), Cabbage looper (CL), Variegated cutworm (VGC), and Western yellowstriped armyworm (WAY).

In each site, traps were replicated two times and maintained operable by replacing lost parts and changing lures once a month.

The sites were distributed in each County as follows (see Appendix C for site details):
Colusa Co.: 2 sites
Merced Co: 2 sites
Sacramento Co.: 2 sites
San Joaquin Co.: 3 sites
Stanislaus Co.: 3 sites
Sutter Co.: 3 sites
Yolo Co.: 2 sites
Fresno Co.: 2 sites

Task 3.2: Data dissemination:. A website was set up in June 2001 (URL: http://www.ipm.ucdavis.edu/PM). Trap counts form all sites were graphed and posted in this website on a weekly basis (Appendix D1-D6). Degree-day accumulation was calculated for each species and site, and displayed on the web site in a graphic format along with the average trap counts. Initially, this website was accessible only to Farm Advisor and the participants PCAs, but it became for public use after assuring of proper performance. With this website it was possible to follow the noctuid populations on a real time basis across the State covering important areas for vegetable crops in the Sacramento and San Joaquin Valleys (Appendix E).
Graphs showed weekly average of trap counts and the degree-days accumulation. Trap data of cabbage looper, for instance, showed that there was an important increase of adult flights early in the season.

Objective 4: Monitoring of larvae populations in the field, data analysis and presentations.

The following tasks were involved in the accomplishment of this objective:

Task 4.1. Field scouting and sampling: PCAs recorded presence of worms in the fields and submitted their records to Farm Advisor to correlate worm/egg presence in the field with trap catches. Worm and egg samples from the field were collected every week by PCAs and submitted to Farm Advisors. These eggs and worms were raised on a food medium and the species was identified at the adult stage.

Task 4.2. Field and trap data analysis: As a result of the evaluation of PCAs notes and samples, we observed that cabbage looper was the only noctuid with significant presence in most of the fields in 2001. Data from more than 80 fields were analyzed and the results are summarized in figures and table in appendix F. Figure 1 depicts new hatches in the field and the expected hatch dates from the phenology model (Degree days/generation = 791.5 F). Each dot represents a field where new hatches were found. The dates predicted with the phenology model fell very close to the peaks of new hatches found in the fields. In fact, peak dates and predicted dates had a highly significant correlation (Fig. 2). There was a larger dispersion of data, reflected by a larger Standard Deviation, at the end of the season probably due to a generation overleaping effect (Table 1). Despite that overleap, the average hatch date 95% Confidence Interval for the third generation was less than four days, which is small enough for practical use of this predictive model.

Task 4.3 Meeting presentations and preparation of reports: Summary of project progress and final results were presented to growers and PCAs in different opportunities as outlined below.

Fresh Market Tomato Grower Meeting: This meeting was held in Stanislaus Co on August 8, 2001 and served to show how to operate pheromone traps and to demonstrate the potential of traps and degree models to time sprays to the period of the most potential for economic damage. The attendance, 30 growers and PCAs, showed interest in this novel approach, and pointed its potential for increasing the efficacy of reduced-risk pesticide.

South Sacramento Valley Processing Tomato Production Meeting: This meeting was held in Woodland on January 8, 2002. Results from field and trap monitoring were presented. The attendee, 150 growers and PCA's, had the opportunity to see the accuracy of this approach to predict worm activity in the field. Several PCA's showed interest in participating in the following season in a similar type of project.

Quad County Tomato Day Meeting: This meeting was held in Stockton on January 23, 2002. There were 120 attendees among Growers and PCA's from San Joaquin, Sacramento, Stanislaus and Contra Costa counties.

Preparation of Reports: Progress report was prepared and submitted on October 4th, 2001 and Final Report was prepared and submitted on August 31, 2002

Summary and Conclusions

This project demonstrated that phenolgy models predicted larvae activity with acceptable accuracy. PCAs can use pheromone trap data to improve field monitoring. Easy access to the regional trap data via World Wide Web provides a real time picture of the evolution of the worm pest population. We have established a statewide system for monitoring noctuid worm pests of vegetable and row crops. The IPM website, which post trap data of participatory counties allows PCAs and growers to track which pests are the most important and to know when they should expect an economically significant population in their region. PCAs had the opportunity to see that trap data were consistent with the observations from the fields that they monitored. We developed a cooperative pest management project across multiple counties, commodities and disciplines that has allowed for increased interaction among PCAs, Farm Advisors and growers. We collected much of the data necessary to demonstrate the usefulness of pheromone traps as a monitoring tool for noctuid pests of vegetable and row crops.

APPENDIX A: Bulletin Pheromone traps and Degree-day models

Using Pheromone Bucket-Traps to Monitor Noctuid Pests: Site Establishment, Operation, and Maintenance

Kent Brittan, Enrique Herrero, and Mike Cahn

Statewide pheromone trapping of noctuid pests requires standardization so that data are not biased by an individual's preferences. The following protocol reflects suggestions from Farm Advisors who have participated in the noctuid monitoring project during the past seasons.

Description of pheromone lures and bucket traps

Bucket traps consist of 4 pieces: a basket to hold the lure, a horizontal shield that fits above the mouth of the trap, a top piece, and a bottom piece (bucket). The shield snaps onto 4 arms protruding a few inches above the top of the bucket, and the top and bottom of the bucket latch together. The lures are suspended in a small basket above the mouth of a bucket trap by inserting the basket into a hole in the center of the shield.

Lures consist of a rubber septa impregnated with sex pheromone specific to a noctuid species. The pheromone attracts male moths to the mouth of the trap and a pesticide strip in the bucket kills trapped moths.

Site selection

Two to three sites are needed to monitor noctuid flights in a county or geographical area. Establish sites within 2 miles of vegetable and row crop fields (processing and freshmarket tomatoes, melons). Choose sites that represent different geographical areas of your county, but are not too far (>20 mi) from a CIMIS or another weather station that records daily air temperature. You can determine the location of weather stations in your county from the UCIPM website.

Locating traps at the field site

Bucket traps of each species that will be monitored are placed in rows along 2-sides of a field site (Figure 1). Keep at least a ¼-mile distance between the rows of traps. Choose locations that are free of obstructions that could block airflow, such as houses, shops, or walls. Also, consider locations that will not be in the way of vehicle traffic and field operations. The side of an irrigation ditch or a berm is often a convenient and safe location to place traps. Finally, because traps are monitored all year, choose locations that are accessible in wet weather, when you may have to walk in from a paved road to check the traps. Traps should be placed at least 100 feet apart within each row (Figure 1).

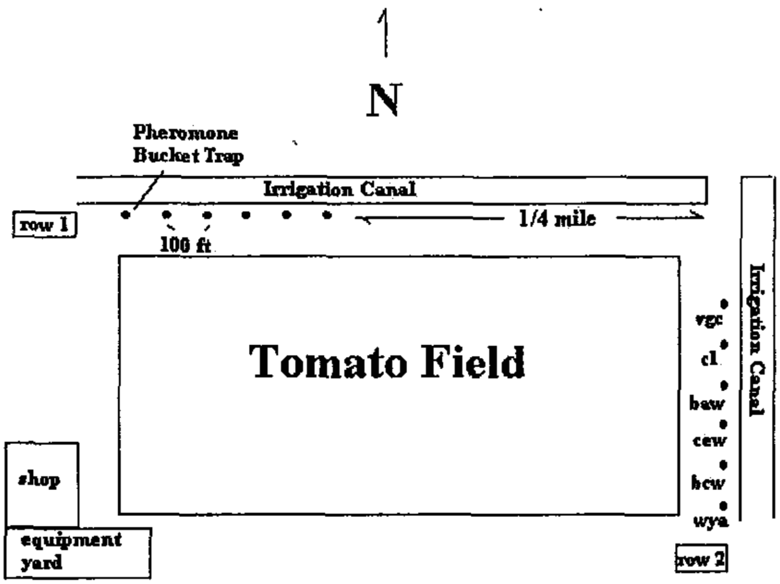


Figure 1. Location of bucket traps at a monitoring site.

Setting up the bucket traps

Each trap should be secured by wire to a stake that is oriented at an angle so that the trap swings free at least 1 ft above the ground. Keep weeds under control so that you can find the traps, and they are visible to tractor operators. Also label the pheromone species on the top and bottom of the trap with a permanent marker. The codes for the species in this study are: BAW (beet armyworm), BCW (black cutworm), CEW (tomato fruit worm), CL (cabbage looper), VGC (variegated cutworm), WYA (western yellowstriped armyworm. Because the plastic of the bucket trap may absorb noctuid pheromone, do not switch the pheromone of a trap to monitor another species.

Follow assembly instructions provided with the traps. The following modifications may improve the performance of the trap:

1. Drill a ¼-in diameter hole near the side of the bottom to drain rain water.

2. Drill a 1/32-in. diameter hole through the rim where the top and bottom parts of the trap come together. Make sure that the two trap halves are secured tightly together when making this small hole. Put a stiff wire with a bend through the hole to secure the top and bottom together during windy conditions.

3. If hanging traps over water, tie a string between the trap and the stake. The string will allow you to retrieve the trap if the wire breaks.

Servicing the traps

Change pheromone lures and pest-strips once per month. It is important to realize that the pheromone compound is easily absorbed and spread to anything that comes in contact with it. Disposable gloves should be worn and changed between traps when replacing lures. Try to avoid touching the new and old lure as you remove them from the foil pouch or the holding basket in the top of the trap. Return the old lure to the foil pouch of the new one and take it with you. Replace the pest strip in the bottom part of the bucket trap with a fresh one. The size of the pest-strip piece should be about a square inch. Do not throw the spent pheromone lures or pest-strips on the ground.

Collecting data

Site data For each trap site record: 1. location of the trap site (lat/long, township/range/section, or nearest intersection) 2. crops grown in fields adjacent to the trap site, 3. name of the closest CIMIS weather station.

Trap data Each trap needs to be checked weekly. The moths are removed from the trap so that they can be identified and counted. When the moth counts are extremely high or it is windy, it may be is easier to bring the moths in a labeled bag to the lab or office for identification and counting. Use the supplied key to identify species from their wing patterns. Record the moth counts on the provided data sheet. If a species is in the wrong trap, it is not added to the total. You can record species that crossover between traps or are not being monitored under separate categories. A "0" indicates that no moths were found in a working trap. It is not uncommon to have missing data due to traps being knocked over, damaged, or vandalized. Events such as these should be recorded with a descriptive code to indicate missing data (Table 1).

Table 1. Missing data codes

ETM: entire trap missing	ETD: entire trap down (on ground)
BM: bottom missing	BD: bottom down
TM: top missing	TD: top down
PM: pesticide strip missing	LD: lure down
LM: lure missing	BB: bottom broken

When closing the trap, make sure that the lure is in place and that the pest-strip is in the bottom of the bucket. Also, check that the bottom and the top of the trap are securely attached.

Disseminating Data

You will eventually enter your data onto the UCIPM web site. Until the website is ready, fax the data sheet each week to Enrique Herrero: 530-673-5368

Table 2. Data sheet for moth traps

BAW = Beet Armyworm	CL = Cabbage Looper
BCW = Black Cutworm	VGC = Variegated Cutworm
CEW = Corn Earworm/Tomato Fruitworm	WYA = Western Yellowstriped Armyworm
Other Spc = Other Species	UnID = Unidentified Species

Date		Location
Trap line #1 side of field traps are located (circle one): N, S, E, W		
Species	**# of Moths**	**# of Cross-over moths (indicate species)**
BAW		
BCW		
CEW		
CL		
VGC		
WAY		
Trap line #2		
BAW		
BCW		
CEW		
CL		
VGC		
WAY		
Date		Location
Trap line #1 side of field traps are located (circle one): N, S, E, W		
Species	**# of Moths**	**# of Cross-over moths (indicate species)**
BAW		
BCW		
CEW		
CL		
VGC		
WAY		
Trap line #2		
BAW		
BCW		
CEW		
CL		
VGC		
WAY		

APPENDIX B: Protocol for Sampling Commercial Fields

Protocol for Sampling Commercial Vegetable and Row Crop Fields for Noctuid Worms and Eggs

Mike Cahn, Enrique Herrero, Carolyn Pickel
UC Cooperative Extension

Materials needed
1. log book
2. blue ice (store in freezer)
3. ice chest/cooler
4. 1 pt plastic ziplock bags
5. sharpie permanent marker
6. pen
7. noctuid worm identification key
8. sampling tray

Terms
Vegetable and row crops include processing tomatoes, fresh market tomatoes, peppers, cucurbits, melons, pumpkins, and dry beans.
Worm sampling procedures include sampling leaves (tomato fruit worm), beating (beat trays), sweeping (sweep net), etc.
Noctuid worm species include: beet armyworm, black cutworm, corn earworm/tomato fruitworm, cabbage looper, variegated cutworm, and western yellowstriped armyworm.
Threshold for presence of worms and eggs in a field is when you find worms/eggs in 10 % or more of the locations sampled.

Procedure

Follow Steps 1-3:
1. Use your normal sampling/scouting procedure.
2. Record in your log book **every day** that you scout vegetable and row crop fields:
   A. Observations summarized for **all fields by commodity** (refer to data sheet examples in Tables 1 and 3)--
      a. date
      b. crop(s)
      c. total number of vegetable and row crop fields scouted by commodity (2 tomato, 5 melon, 3 cucurbit fields)
      d. number of fields with presence of worms by commodity. (categorize by species if possible)
      e. comments about infestation level (low, medium, high) and worm size (small, medium, large), and other significant facts (insecticides applied, economic damage observed).

OR

B. Observations summarized **by individual fields** (refer to data sheet examples in Tables 2 and 4)--

a. date
b. crop
c. field identification number
d. presence or absence of worms and eggs by species (beet armyworm, black cutworm, unidentified, etc).
e. comments on infestation (low, medium, high) and worm sizes (small, medium, large), and other significant facts (insecticides applied, economic damage observed).

3. Collect worm and egg samples once or twice per week when you scout vegetable and row crop fields:

A. Collect a representative sample of eggs/worms from each field scouted.
B. Place eggs and worms in a ziplock bag with leaves (one bag per field).
C. Mark the grower name, crop, field number, and date on the bag (Figure 1.)
D. Put bags into cooler with "blue ice."
E. Bring cooler with samples back to your office.
F. UC Farm Advisor will pick up samples from your office and grow worms and eggs to the adult stage for identification.

Figure 1. Required labeling on ziplock sample bag.

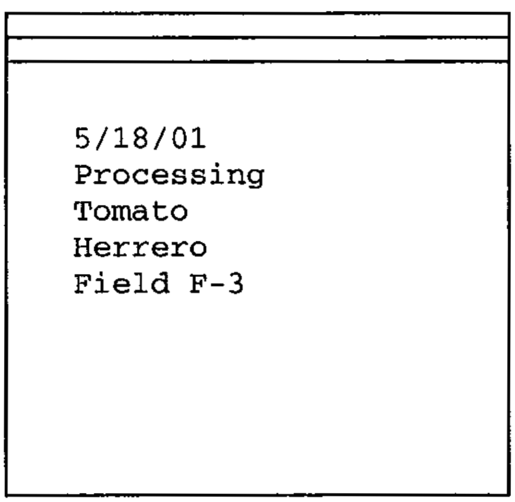


Table 1. Example of summarizing worm infestations for all fields by commodity

BAW = Beet Armyworm	CL = Cabbage Looper
BCW = Black Cutworm	VGC = Variegated Cutworm
CEW = Corn Earworm/Tomato Fruitworm	WYA = Western Yellowstriped Armyworm
Other Spc = Other Species	UnID = Unidentified Species

Threshold of presence is when greater than 10 % of locations scouted have worms/eggs

		Total #	------------------------ **number of fields with worms**								
Date	Crop	of Fields	BAW	BCW	CEW	CL	VGC	WYA"	Other Spc	UnID	Comments
5/1/01	melon	3	2	0	1	1	0	1	0	2	Low pop. of BAW
	pepper	2	0	0	1	0	0	1	1	2	medium CEW
	p.tomato	7	1	0	0	0	0	0	0	1	small BAW
5/2/01	melon	4	1	0	1	0	0	1	0	2	Low pop. of BAW
	p.tomato	5	2	0	1	0	0	1	0	2	worm eggs

Table 2. Example of summarizing worm infestations of individual fields

BAW = Beet Armyworm BCW = Black Cutworm CEW = Corn Earworm/Tomato Fruitworm Other Spc = Other Species	CL = Cabbage Looper VGC = Variegated Cutworm WYA = Western Yellowstriped Armyworm UnID = Unidentified Species

- = not present at any of the locations sampled
\+ = low presence level (present at less than 10% of the locations sampled)
++ = medium level of presence (present at 10-25% of locations scouted within a field)
+++ = high level of presence level (present at greater than 25% of the locations sampled)

			------------------------ level of presence ----------------------------								
Date	Crop	Field #	BAW	BCW	CEW	CL	VGC	WAY"	Other Spc	UnID	Comments
5/1/01	melon	1-E	+	-	+	-	-	+	-	-	low pop. of BAW
	pepper	A-1	+	-	+	-	-	+	-	+	medium size CEW
	pepper	F-2	+	-	+	-	-	-	-	-	worm eggs
	melon	1	+	-	+	-	-	+	-	-	worm eggs
	p.tomato	4	+	-	+	-	-	+	-	-	small BAW
5/2/01	melon	A-2	+	-	+	-	-	+	-	-	small BAW
	pepper	A-5	+	-	+	-	-	+	-	+	small worms and eggs
	pepper	F-3	-	-	+	-	-	-	-	-	small worms and eggs
	melon	F-4	-	-	-	-	-	+	-	-	
	p.tomato	F-5	-	-	++	-	-	+	-	+	small worms and eggs
	p.tomato	F-6	-	-	+	-	-	+	-	+	eggs
	p.tomato	F-7	+	-	+	-	-	+	+	+	small BAW
	p.tomato	F-8	+	-	++	-	-	++	+	-	small BAW
	p.tomato	F-9	+	-	+	-	-	+	-	-	small BAW

Table 3. Blank data sheet for summarizing worm infestations for all fields **by commodity**. This is an example of how to set up your logbook for data entry.

BAW = Beet Armyworm	CL = Cabbage Looper
BCW = Black Cutworm	VGC = Variegated Cutworm
CEW = Corn Earworm/Tomato Fruitworm	WYA = Western Yellowstriped Armyworm
Other Spc = Other Species	UnID = Unidentified Species

The threshold for the presence is when 10% or more of the locations scouted have worms and/or eggs

			------------------------ number of fields with worms ----------------								
Date	Crop	Total # ------------ of Fields	BAW	BCW	CEW	CL	VGC	WYA"	Other Spc	UnID	Comments

Table 4. Blank data sheet for summarizing worm infestations **by individual fields.** This is an example of how to set up your logbook for data entry.

BAW = Beet Armyworm	CL = Cabbage Looper
BCW = Black Cutworm	VGC = Variegated Cutworm
CEW = Corn Earworm/Tomato Fruitworm	WYA = Western Yellowstriped Armyworm
Other Spc = Other Species	UnID = Unidentified Species
- = not present at any of the locations sampled	
+ = low presence level (present at less than 10% of the locations sampled)	
++ = medium level of presence (present at 10-25% of locations scouted within a field)	
+++ = high level of presence level (present at greater than 25% of the locations sampled)	

			------------------------ level of presence ------------------- ---------								
Date	Crop	Field #	BAW	BCW	CEW	CL	VGC	WYA"	Other Spc	UnID	Comments

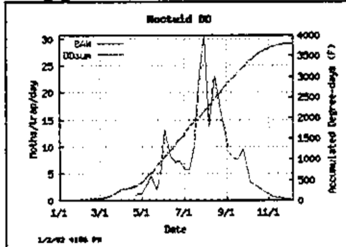
Table 5. Blank data sheet for logging in worm and egg samples collected in commercial row and vegetable crop fields.

ID #	Collection Date	Initial Stage	Larvae ID	PCA	Grower	Field	Crop	Adult ID

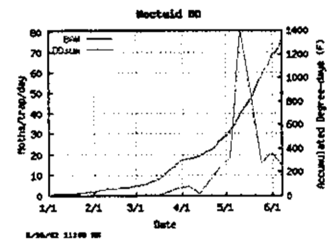
Appendix C: Site locations by County

County	Site Location
Colusa County	Grimes Maxwell
Merced County	Live Oak Farms Los Banos
Sacramento County	Natomas Russel Road
San Joaquin County	Farmington Lodi Vernalis
Stanislaus County	Marshall Modesto Ripon
Sutter County	Acme Road Drexler Road Pelger Road
Yolo County	Knights Landing SE Woodland
Fresno County	Cantua Creek Westside Field Station

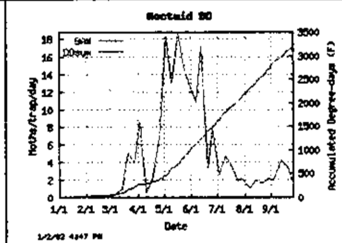
Appendix D1: BAW trap counts form the IPM website



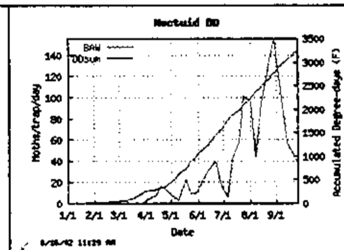
Tule Rd, Colusa



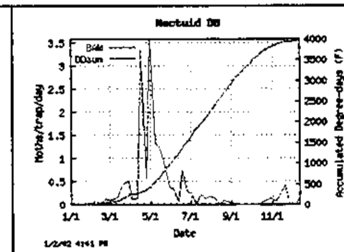
WSREC, Fresno



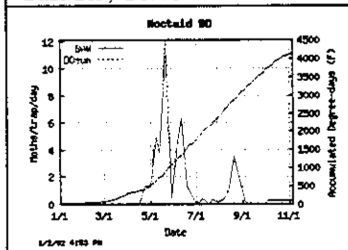
Russel Rd, Sacramento



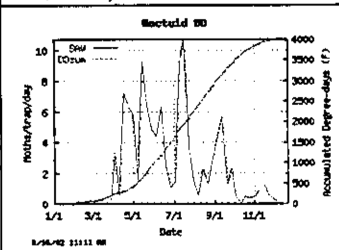
Crows Landing, Srtanislaus



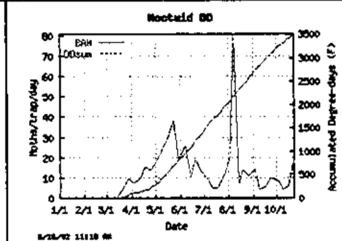
Drexler Rd, Sutter



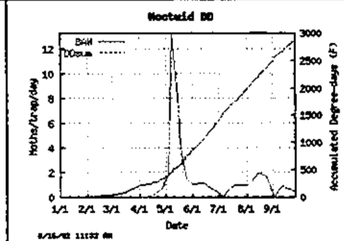
McDermort Rd, Colusa



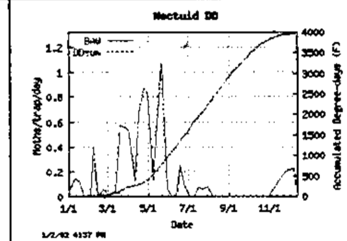
Live Oak Farms, Merced



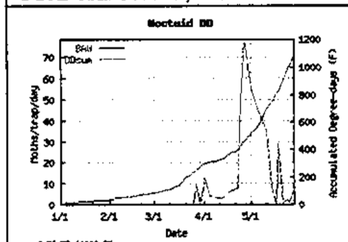
Farmington, San Joaquin



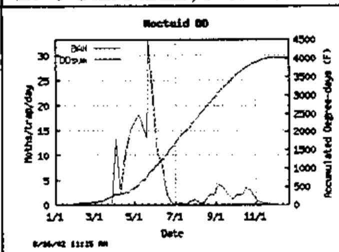
Modesto, Stanislaus



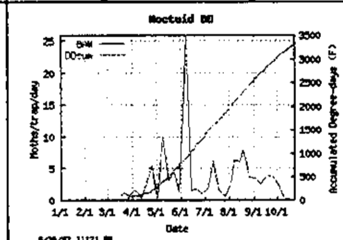
Pelger Rd, Sutter



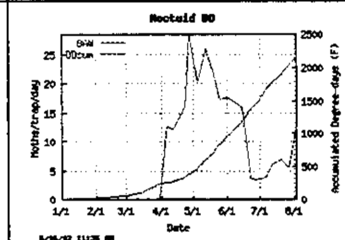
C. Creek Field 19, Fresno



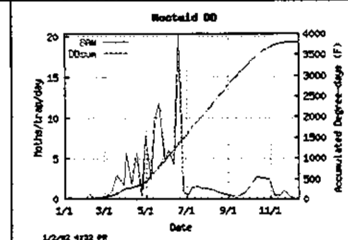
Los Banos, Merced



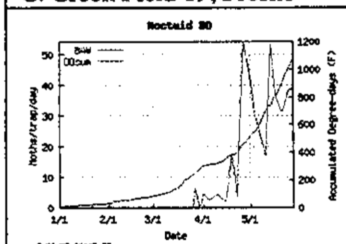
Lodi, San Joaquin



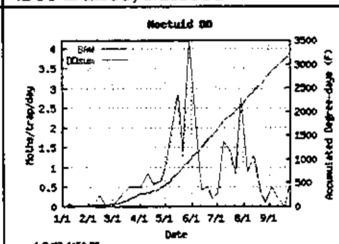
Ripon, Stanislaus



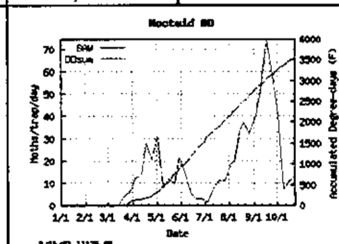
Knights Landing, Yolo



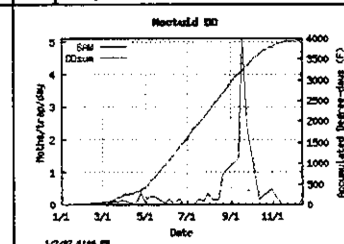
C. Creek Field 21, Fresno



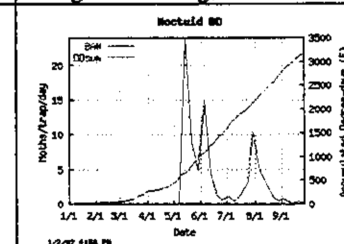
Natomas, Sacramento



Vernalis, San Joaquin

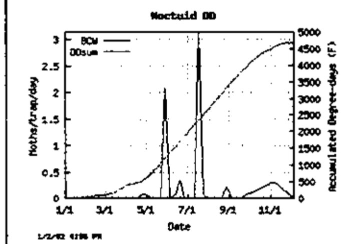


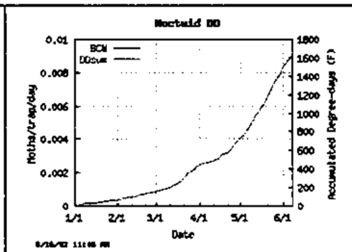
Acme Rd, Sutter

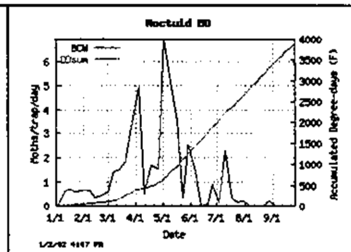


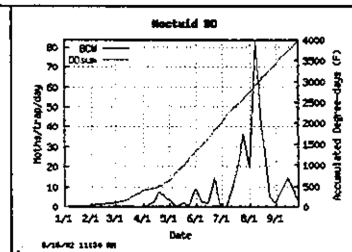
Woodland, Yolo

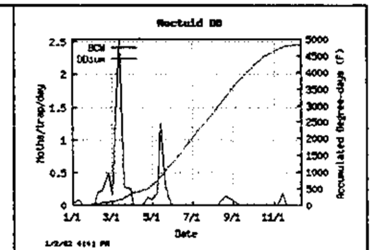
Appendix D2: BCW trap counts form the IPM website

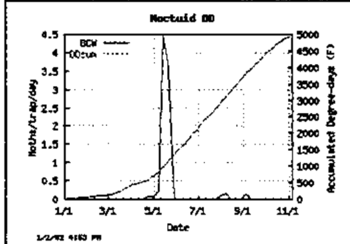

Tule Rd, Colusa

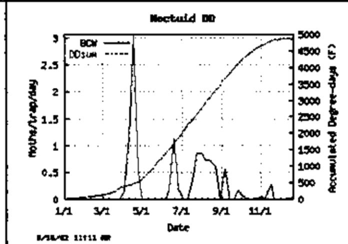

WSREC, Fresno

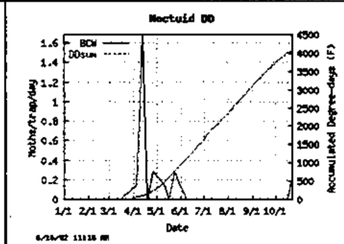

Russel Rd, Sacramento

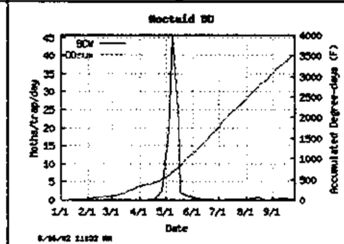

Crows Landing, Srtanislaus

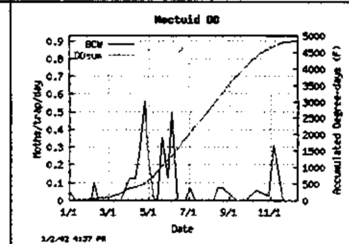

Drexler Rd, Sutter

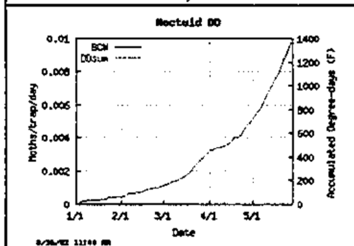

McDermort Rd, Colusa

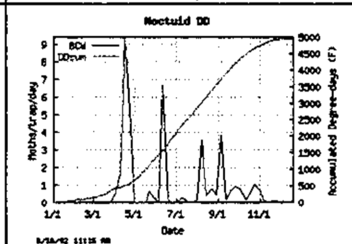

Live Oak Farms, Merced

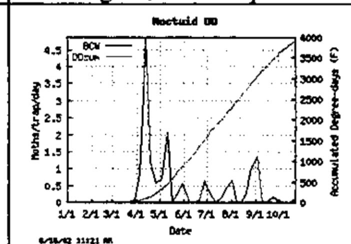

Farmington, San Joaquin

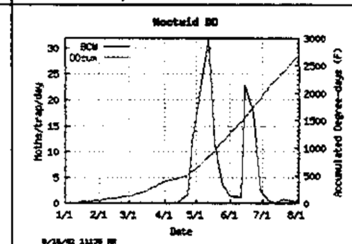

Modesto, Stanislaus

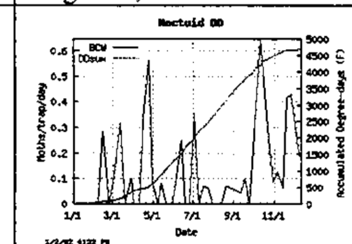

Pelger Rd, Sutter

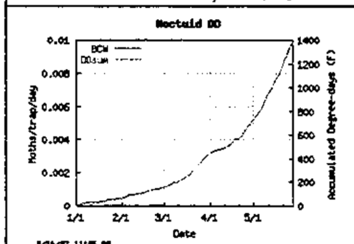

C. Creek Field 19, Fresno

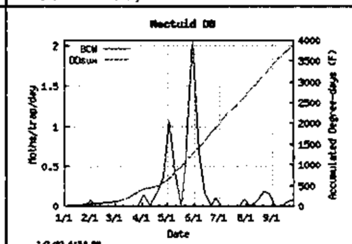

Los Banos, Merced

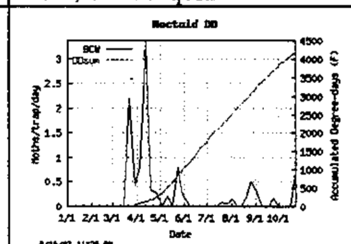

Lodi, San Joaquin

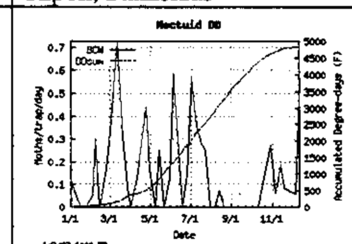

Ripon, Stanislaus

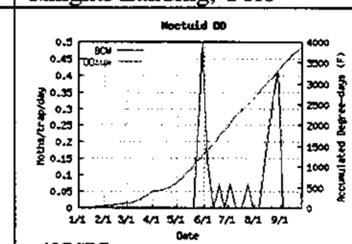

Knights Landing, Yolo


C. Creek Field 21, Fresno

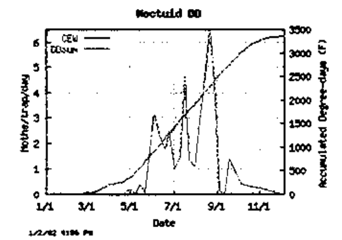

Natomas, Sacramento

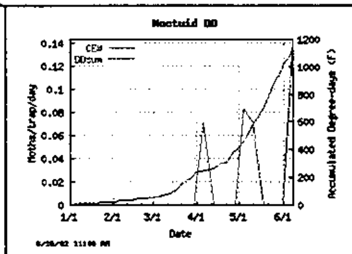

Vernalis, San Joaquin

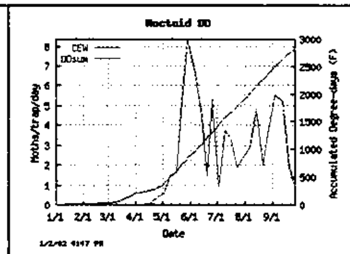

Acme Rd, Sutter

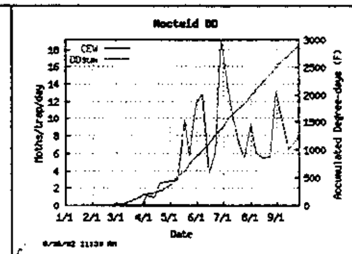

Woodland, Yolo

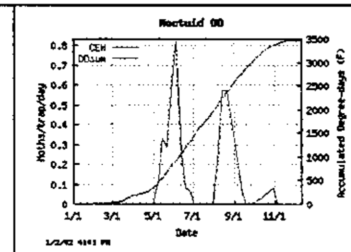
Appendix D3: CEW trap counts form the IPM website

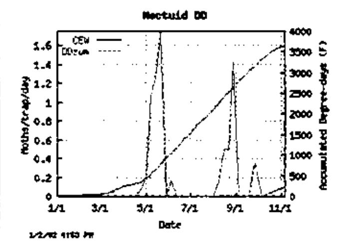

Tule Rd, Colusa

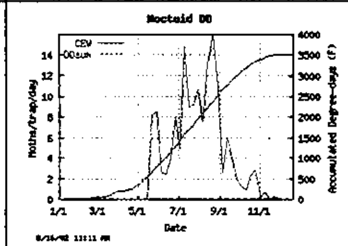

WSREC, Fresno

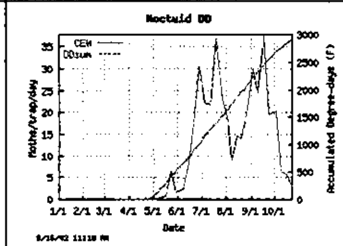

Russel Rd, Sacramento

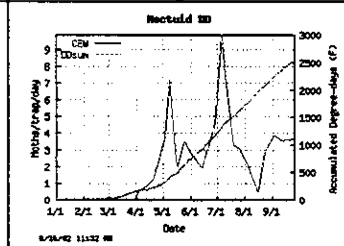

Crows Landing, Srtanislaus

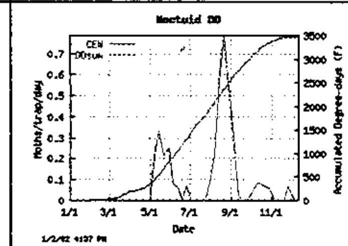

Drexler Rd, Sutter

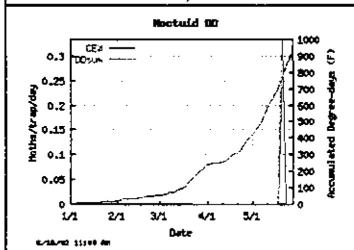

McDermort Rd, Colusa

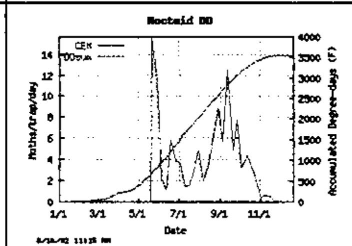

Live Oak Farms, Merced

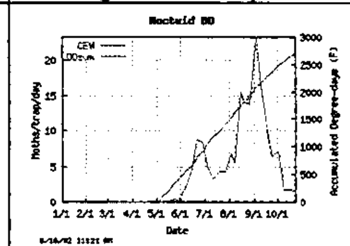

Farmington, San Joaquin

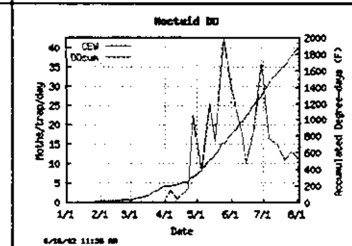

Modesto, Stanislaus

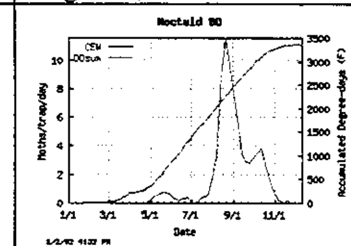

Pelger Rd, Sutter

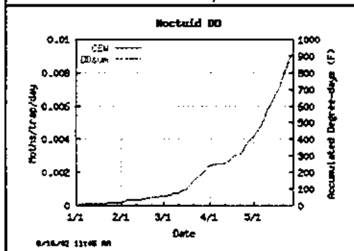

C. Creek Field 19, Fresno

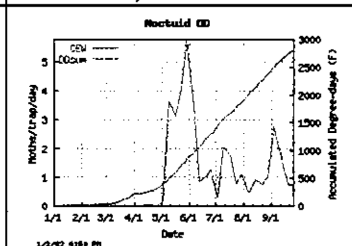

Los Banos, Merced

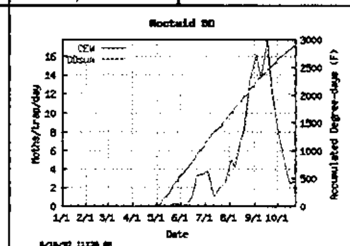

Lodi, San Joaquin

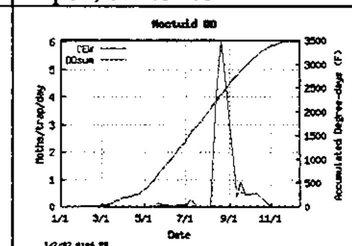

Ripon, Stanislaus

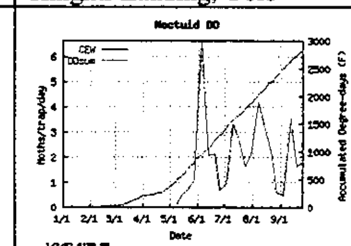

Knights Landing, Yolo


C. Creek Field 21, Fresno

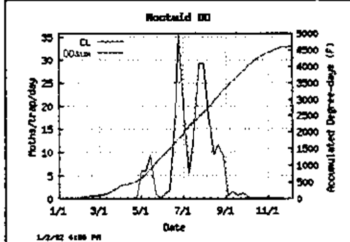

Natomas, Sacramento


Vernalis, San Joaquin

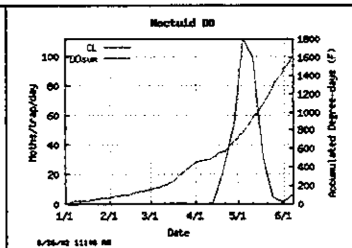

Acme Rd, Sutter


Woodland, Yolo

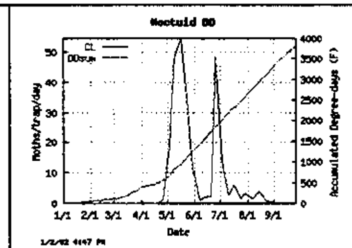
Appendix D4: CL trap counts form the IPM website



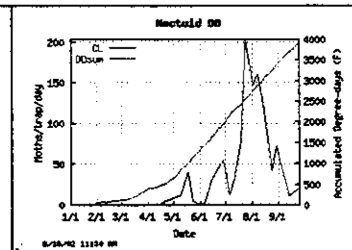
Tule Rd, Colusa



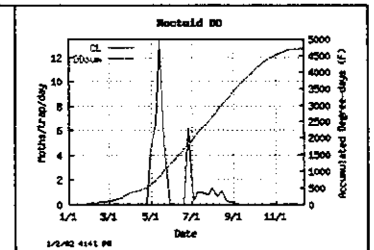
WSREC, Fresno



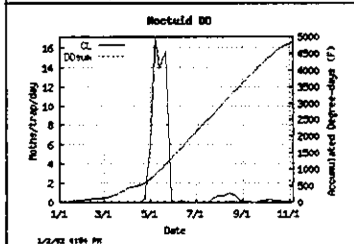
Russel Rd, Sacramento



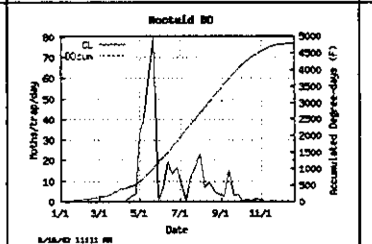
Crows Landing, Srtanislaus



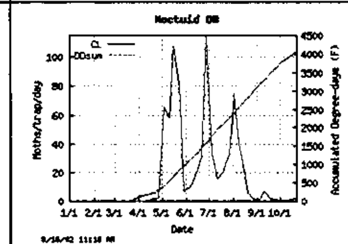
Drexler Rd, Sutter



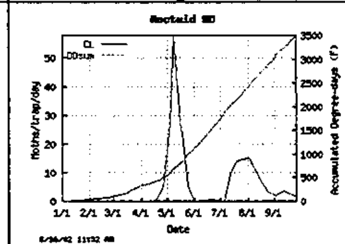
McDermort Rd, Colusa



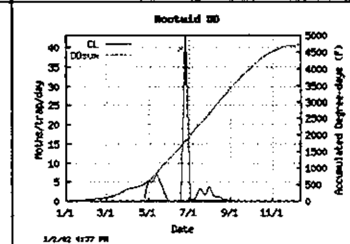
Live Oak Farms, Merced



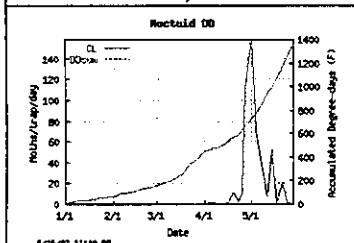
Farmington, San Joaquin



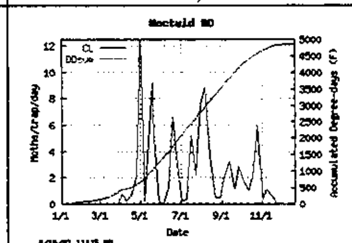
Modesto, Stanislaus



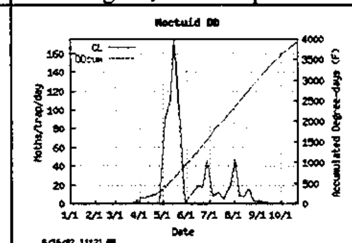
Pelger Rd, Sutter



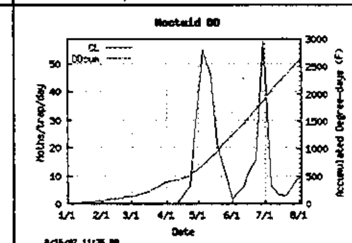
C. Creek Field 19, Fresno



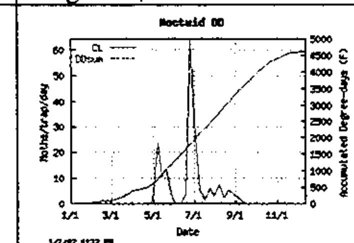
Los Banos, Merced



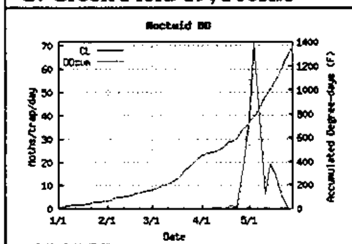
Lodi, San Joaquin



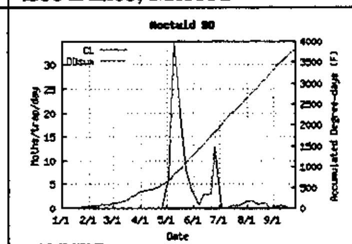
Ripon, Stanislaus



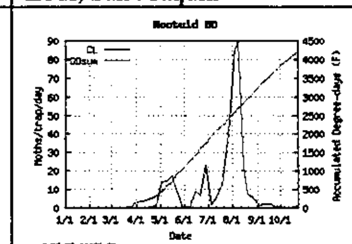
Knights Landing, Yolo



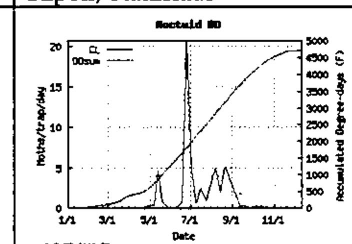
C. Creek Field 21, Fresno



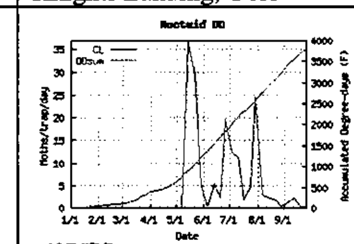
Natomas, Sacramento



Vernalis, San Joaquin

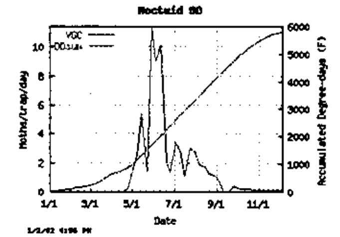


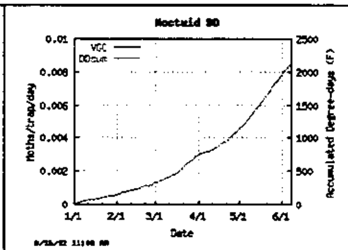
Acme Rd, Sutter

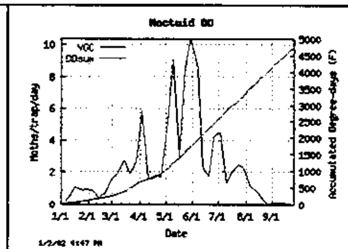


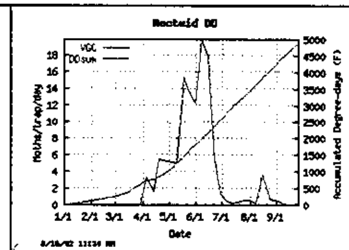
Woodland, Yolo

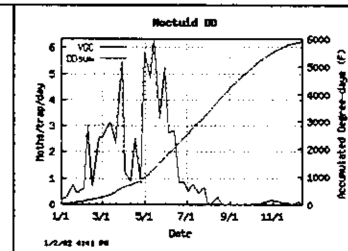
Appendix D5: VGC trap counts form the IPM website

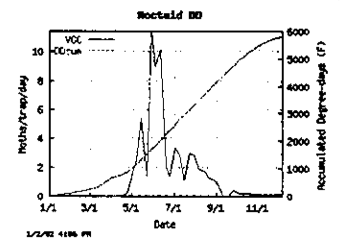

Tule Rd, Colusa

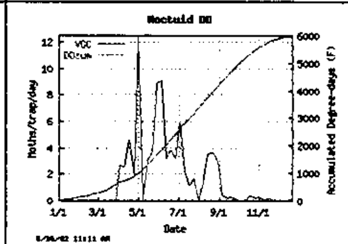

WSREC, Fresno

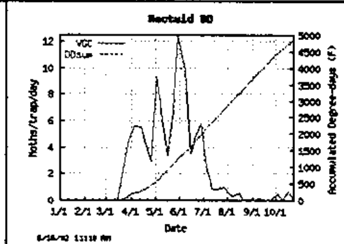

Russel Rd, Sacramento

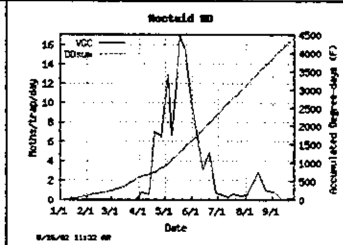

Crows Landing, Srtanislaus

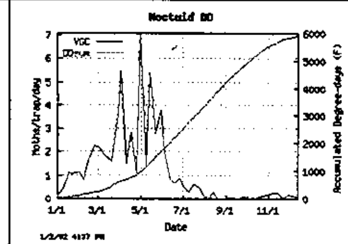

Drexler Rd, Sutter

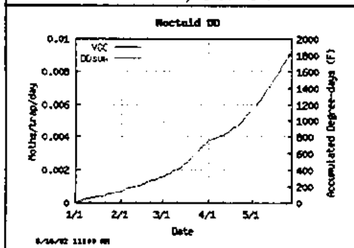

McDermort Rd, Colusa

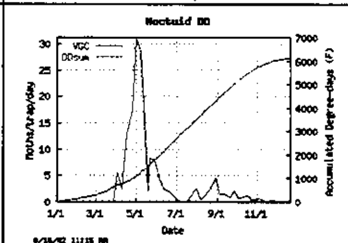

Live Oak Farms, Merced

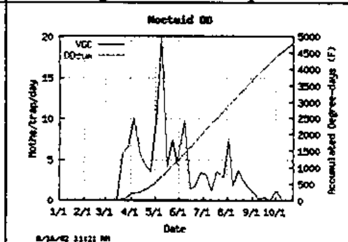

Farmington, San Joaquin

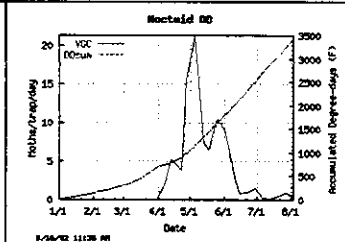

Modesto, Stanislaus

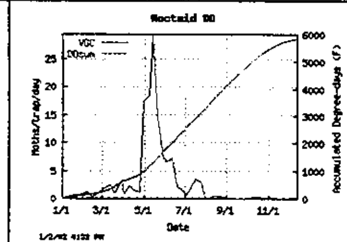

Pelger Rd, Sutter

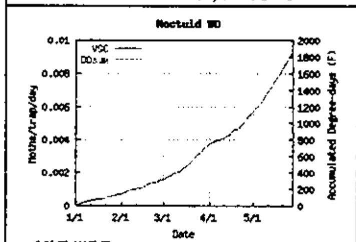

C. Creek Field 19, Fresno

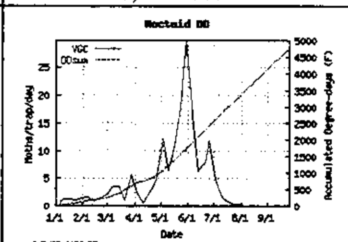

Los Banos, Merced

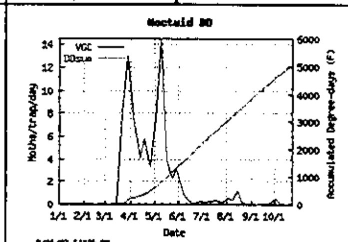

Lodi, San Joaquin

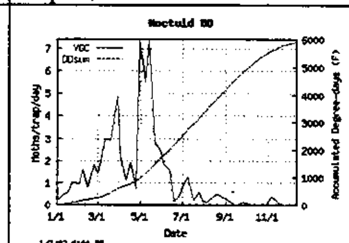

Ripon, Stanislaus

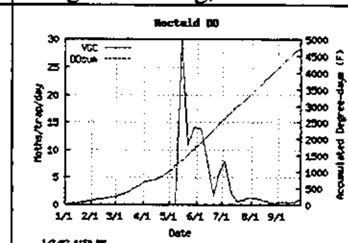

Knights Landing, Yolo


C. Creek Field 21,

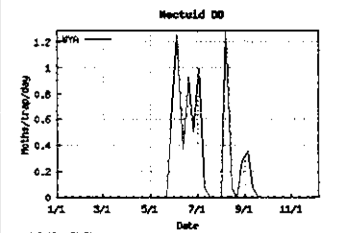

Natomas, Sacramento


Vernalis, San Joaquin

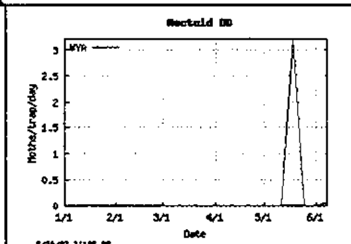

Acme Rd, Sutter


Woodland, Yolo

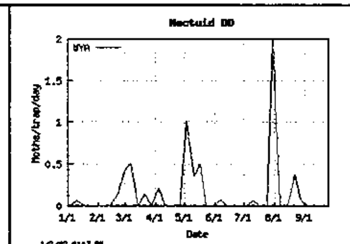
Appendix D6: WYA trap counts form the IPM website



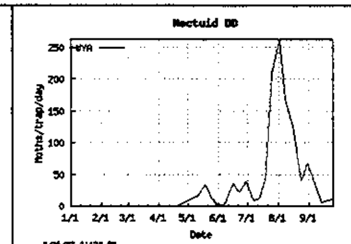
Tule Rd, Colusa



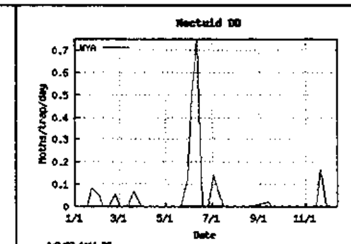
WSREC, Fresno



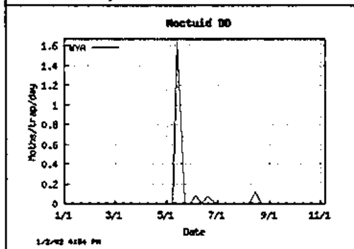
Russel Rd, Sacramento



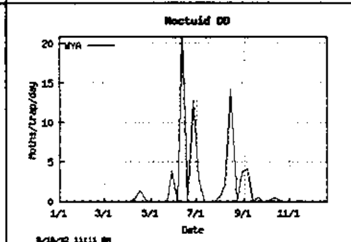
Crows Landing, Srtanislaus



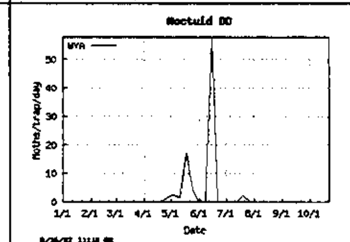
Drexler Rd, Sutter



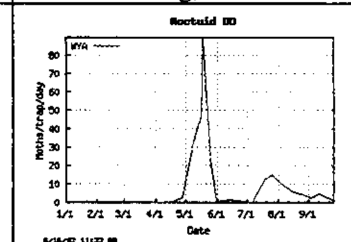
McDermort Rd, Colusa



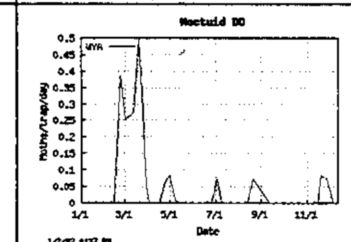
Live Oak Farms, Merced



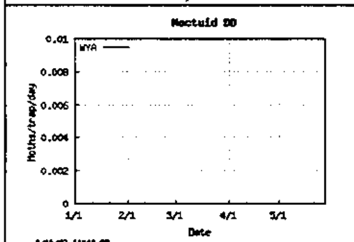
Farmington, San Joaquin



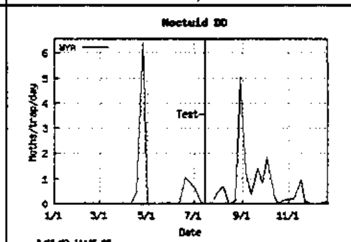
Modesto, Stanislaus



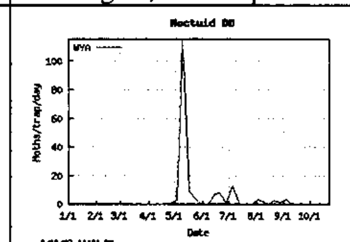
Pelger Rd, Sutter



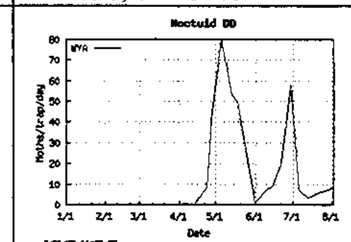
C. Creek Field 19, Fresno



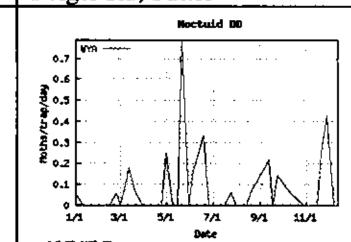
Los Banos, Merced



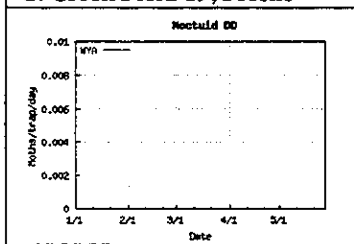
Lodi, San Joaquin



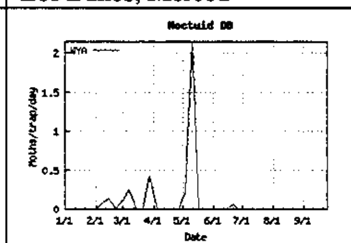
Ripon, Stanislaus



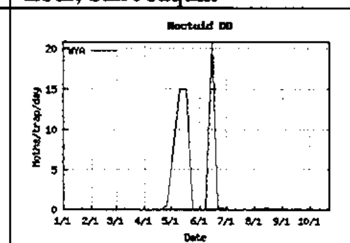
Knights Landing, Yolo



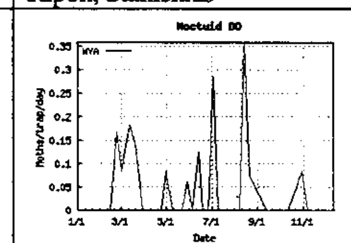
C. Creek Field 21, Fresno



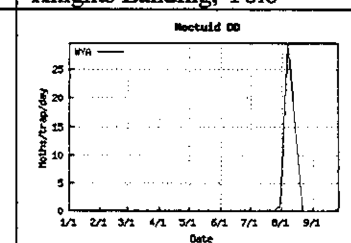
Natomas, Sacramento



Vernalis, San Joaquin



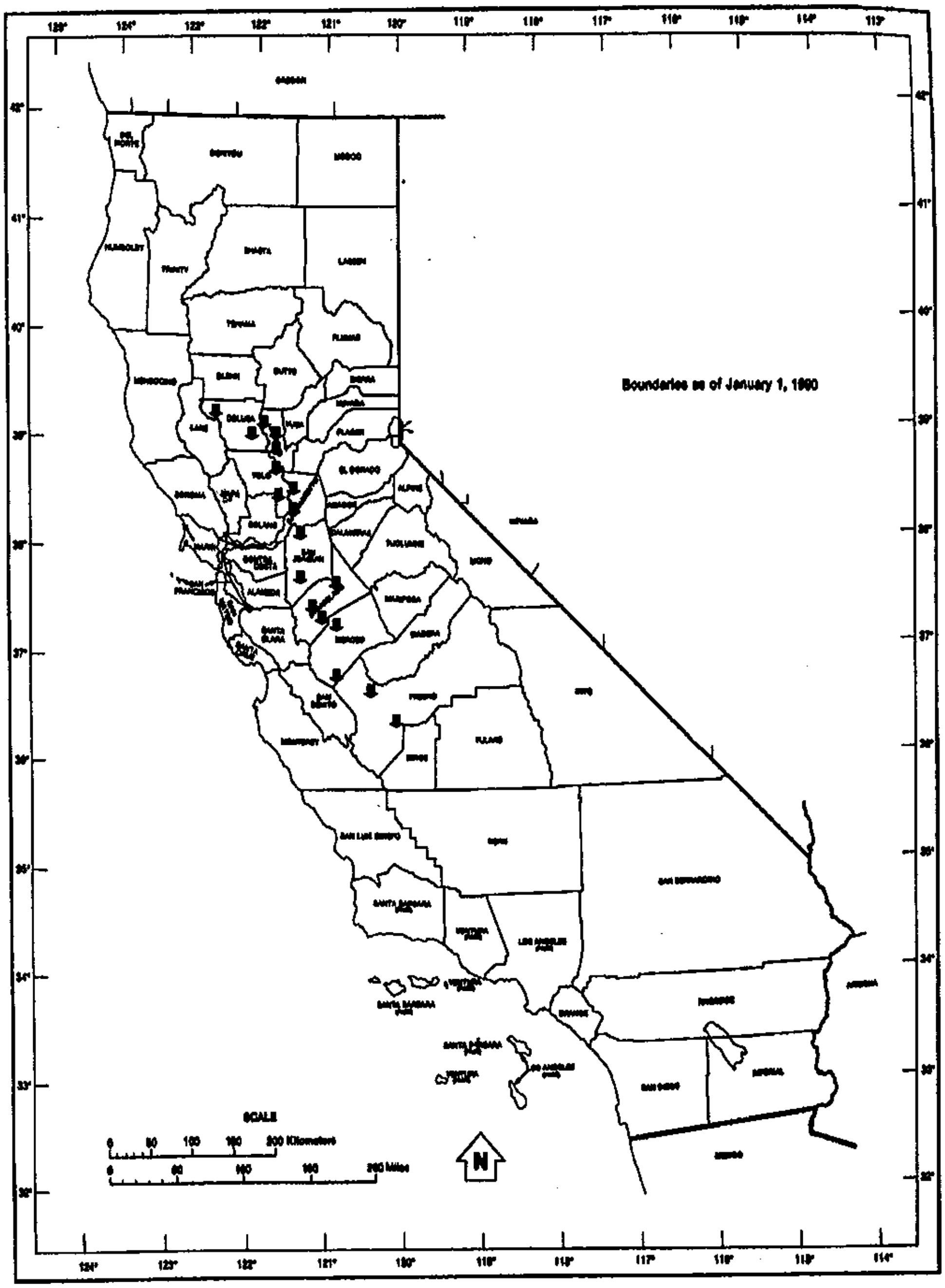
Acme Rd, Sutter



Woodland, Yolo

Appendix E: Map location of trap sites across the Sacramento and San Joaquin Valleys

Counties



U.S. DEPARTMENT OF COMMERCE Economics and Statistics Administration Bureau of the Census
MAPS

CALIFORNIA G-1

Appendix F: Field monitoring data summary

Figure 1: New CL hatch frequency and expected hatch dates.

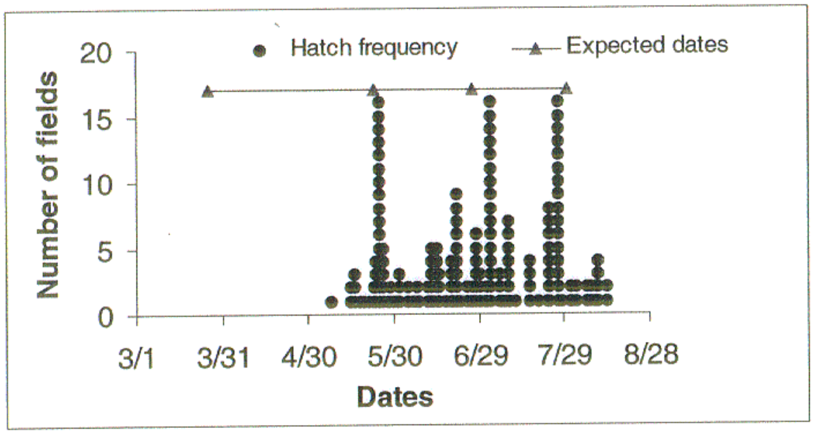


Figure 2: Correlation between observed peaks and expected CL hatch dates.

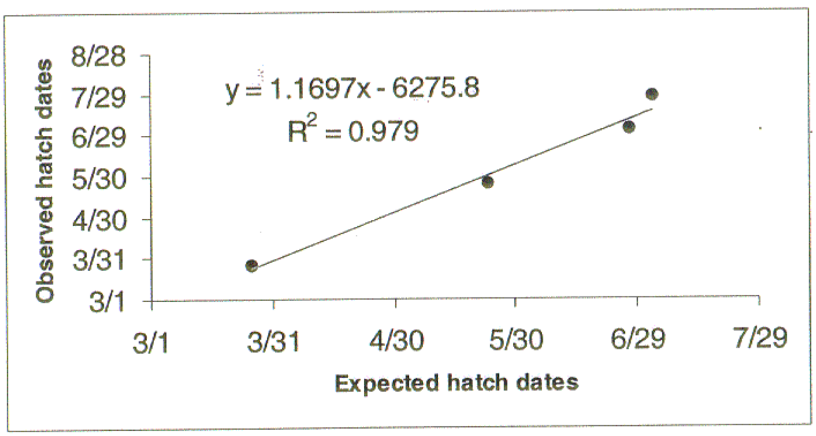


Table 1: Model, peak and average CL hatch dates by generation and SD and 95% CI. of the average date.

Generation	Expected hatch date	Hatch peak date	Average hatch date	Standard deviation (days)	95% Conf. interval (days)
First	5/23/01	5/25/01	5/25/01	6.3	1.8
Second	6/27/01	7/03/01	6/26/01	8.9	2.0
Third	7/30/01	7/27/01	7/28/01	13.1	3.7